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(54) **CASING EQUIPMENT FOR PULSED POWER DRILLING**

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E21B 7/24 (2006.01)

(52) **U.S. Cl.**
CPC ***E21B 33/165*** (2020.05); ***E21B 7/24*** (2013.01)

(58) **Field of Classification Search**
CPC E21B 33/05; E21B 33/16; E21B 33/165; E21B 33/167
See application file for complete search history.

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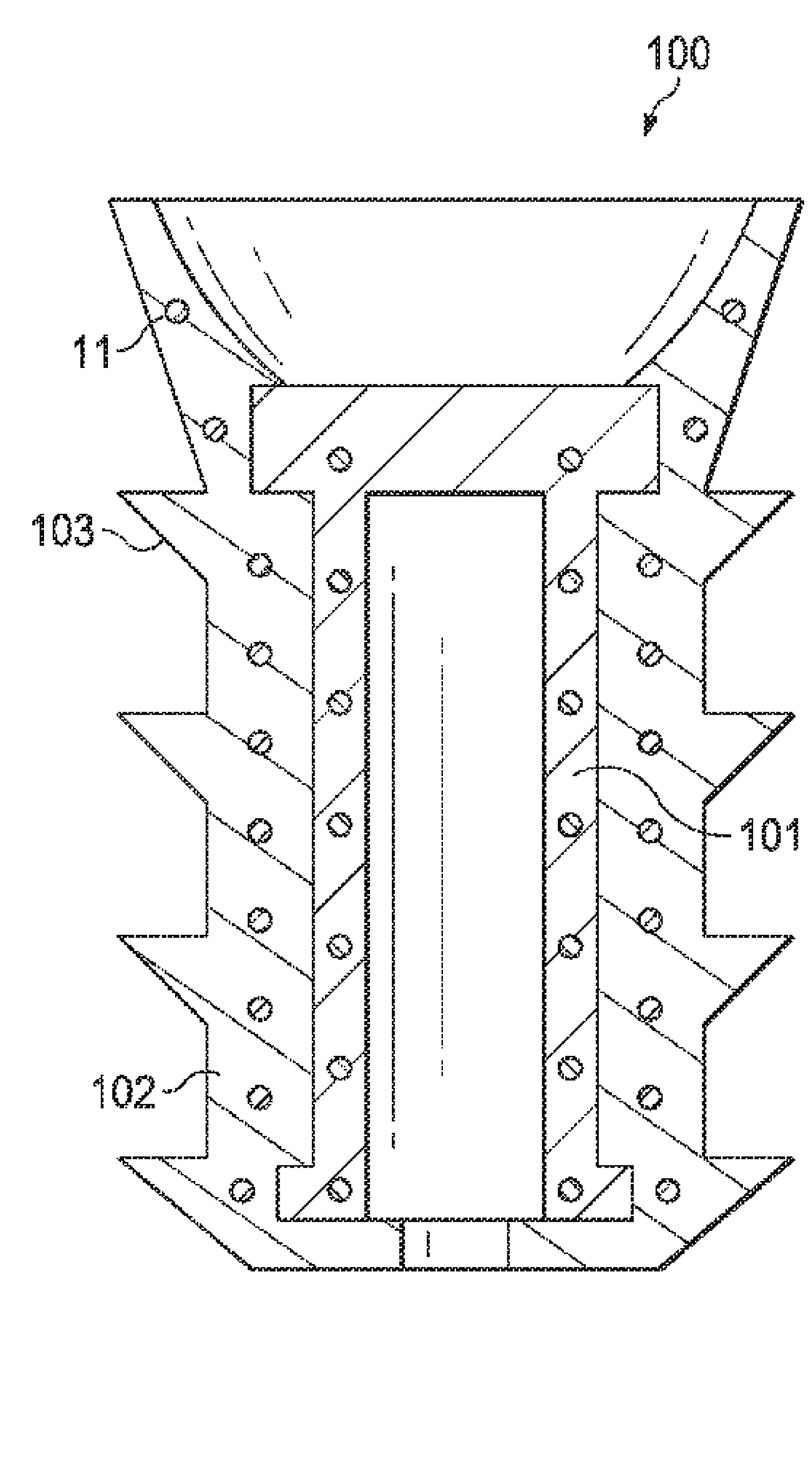
(57) **ABSTRACT**

The present disclosure includes a plug for cementing a wellbore. The plug may include a cylinder. The cylinder may include at least one body including a non-conductive material with conductive filaments dispersed within the non-conductive material. The present disclosure also includes float equipment for cementing a wellbore. The float equipment may include a casing segment including an inner surface, drillable material affixed to the inner surface of the casing segment, and a check valve attached to the drillable material. The drillable material may include a non-conductive material and conductive filaments dispersed within the non-conductive material.

18 Claims, 14 Drawing Sheets



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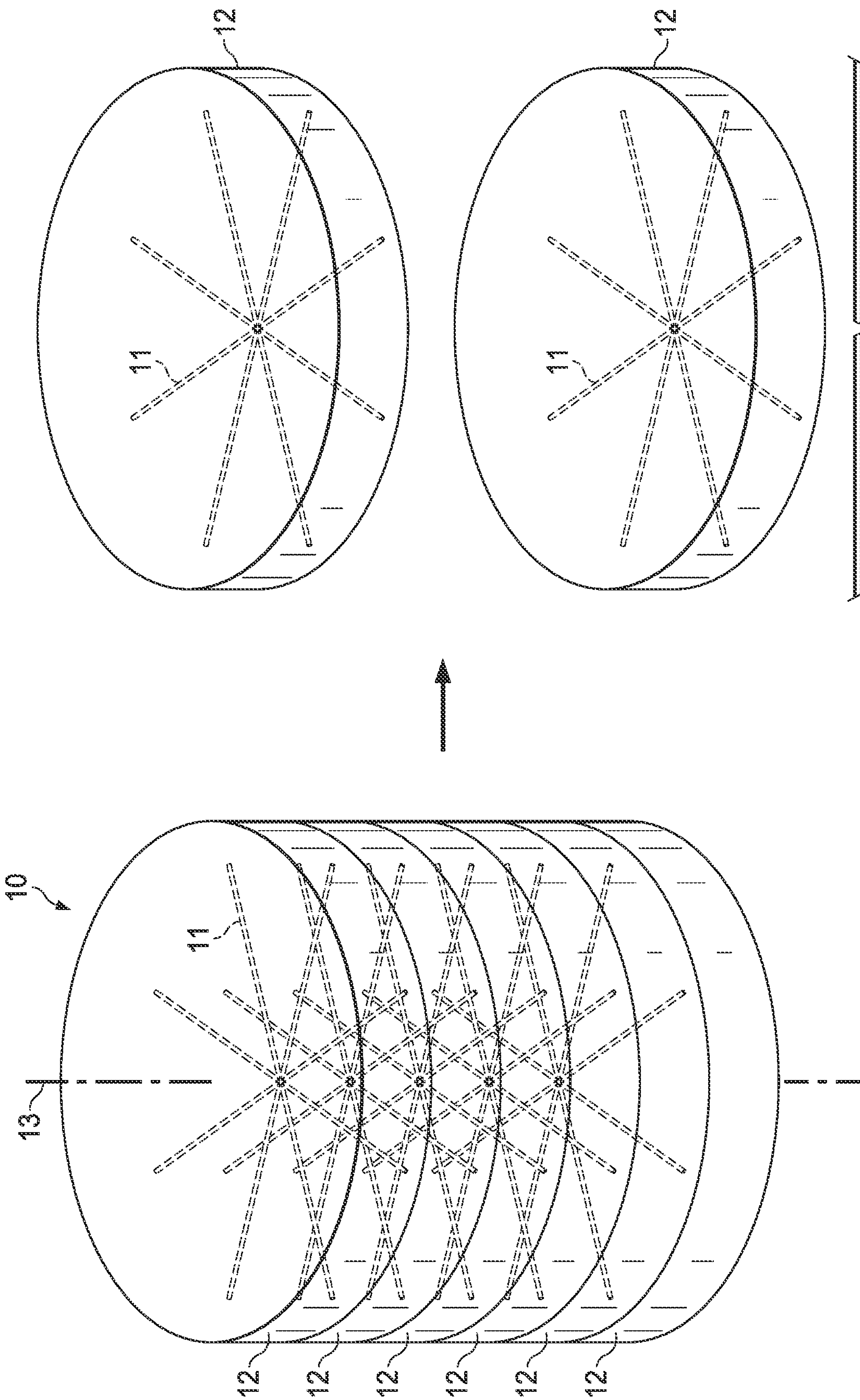


FIG. 1A

FIG. 1B

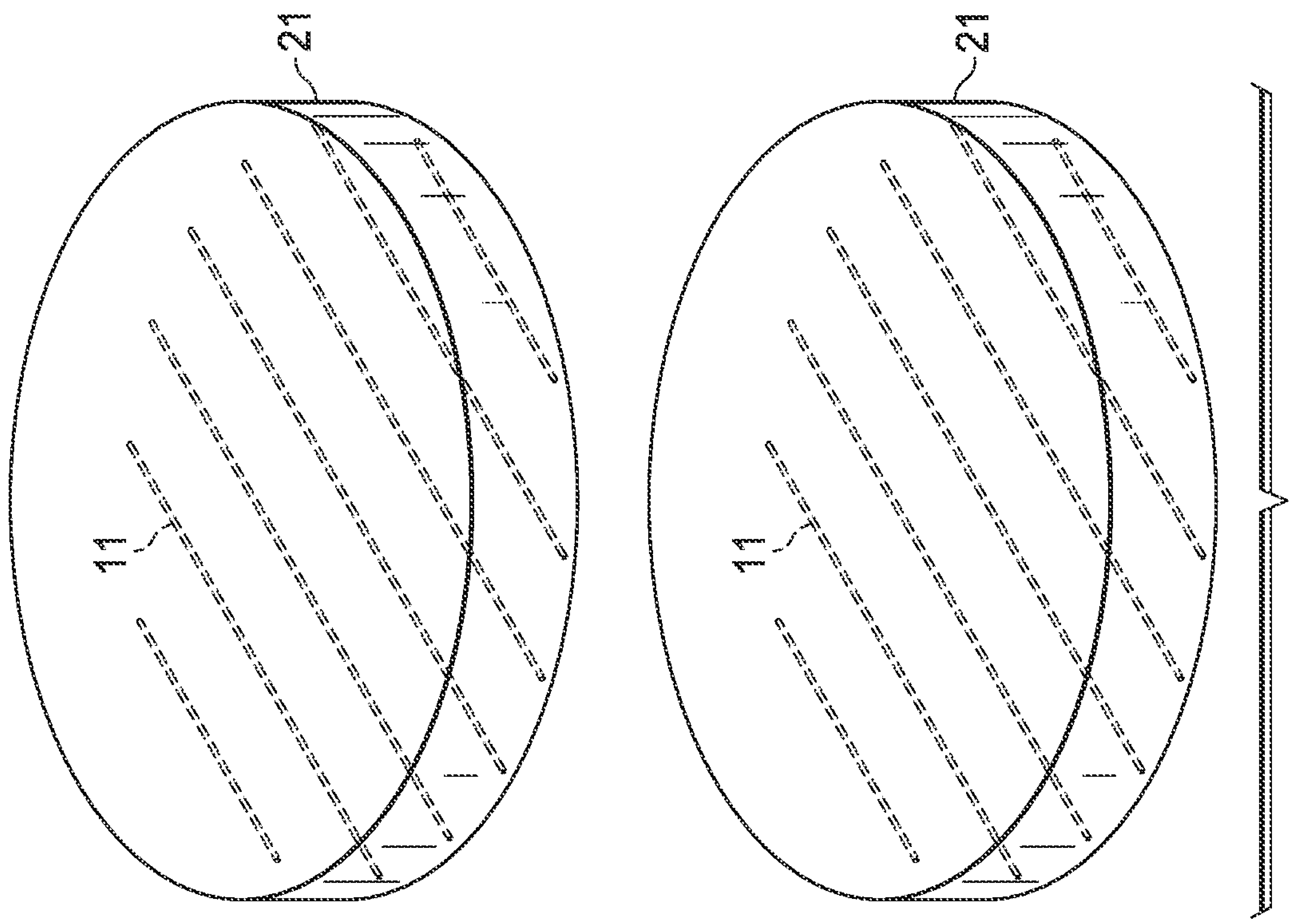


FIG. 2B

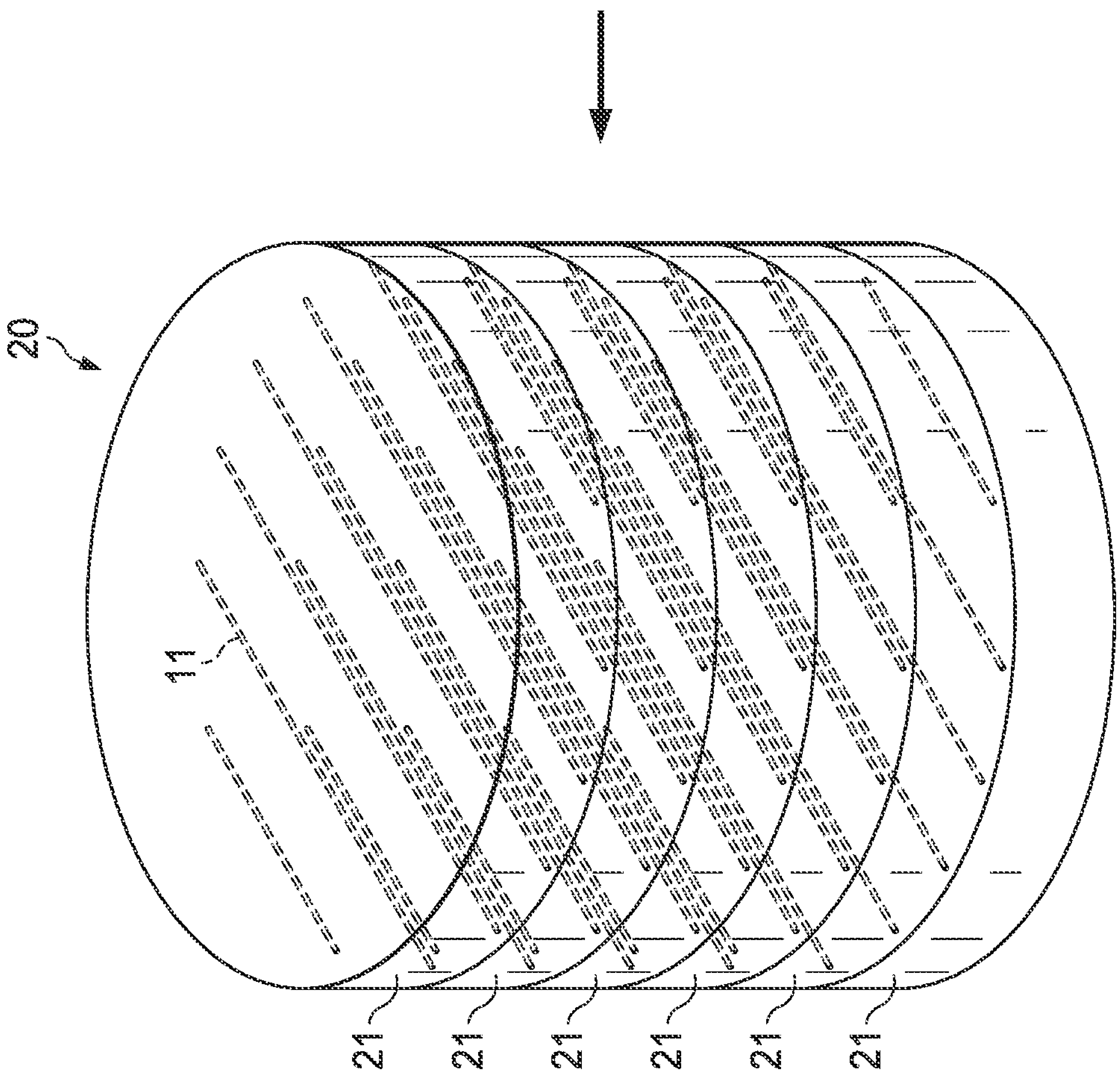


FIG. 2A

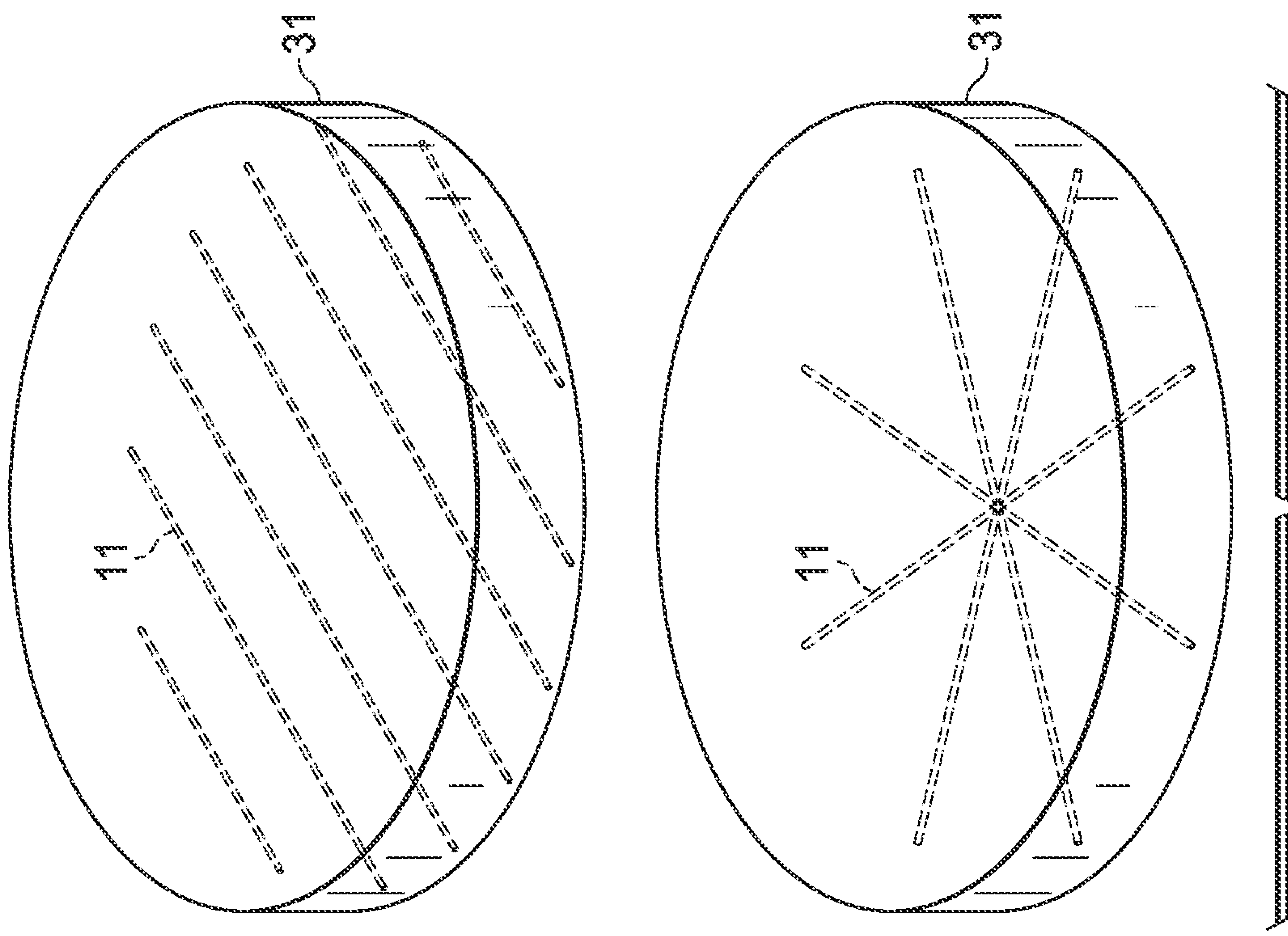


FIG. 3B

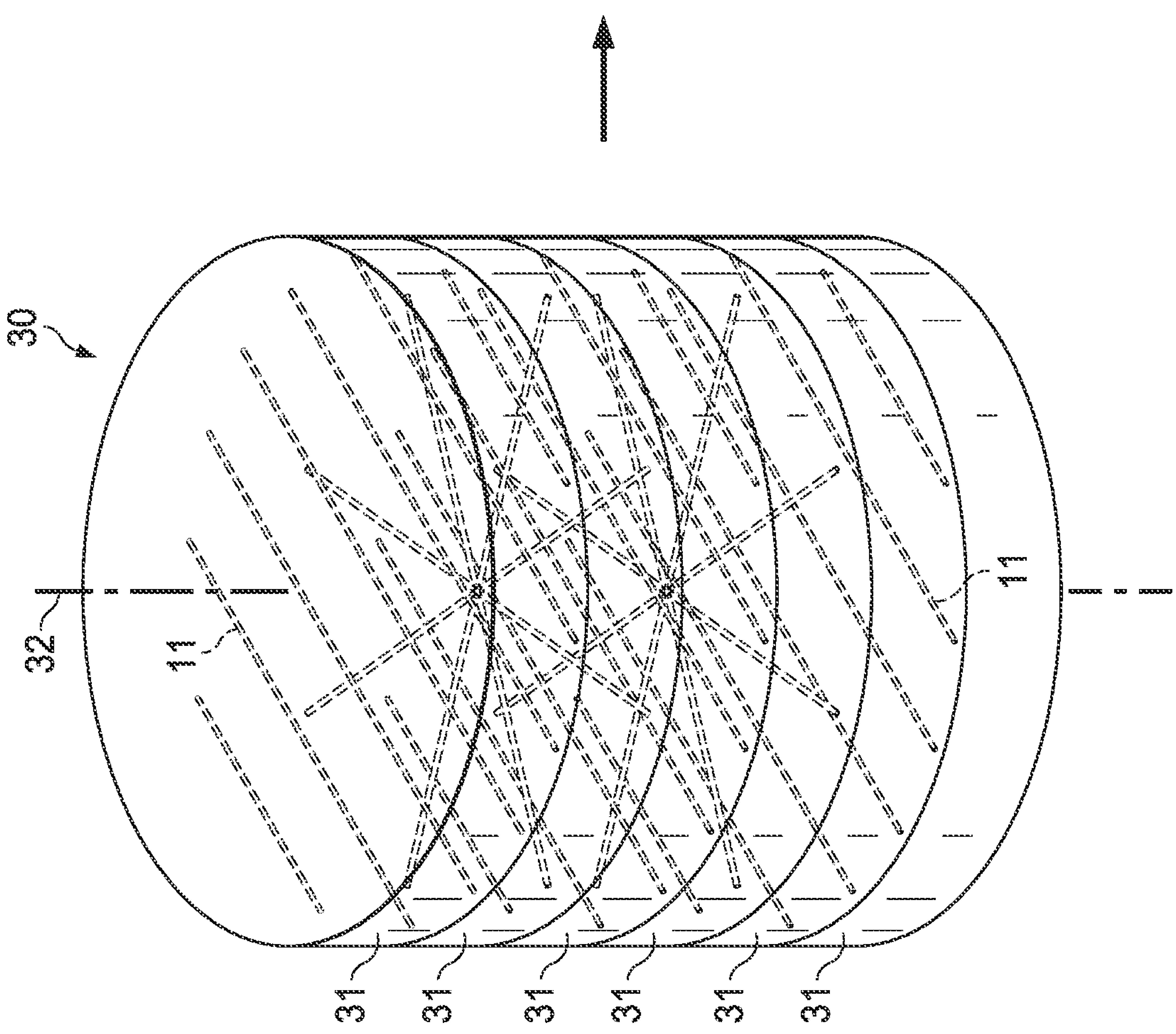


FIG. 3A

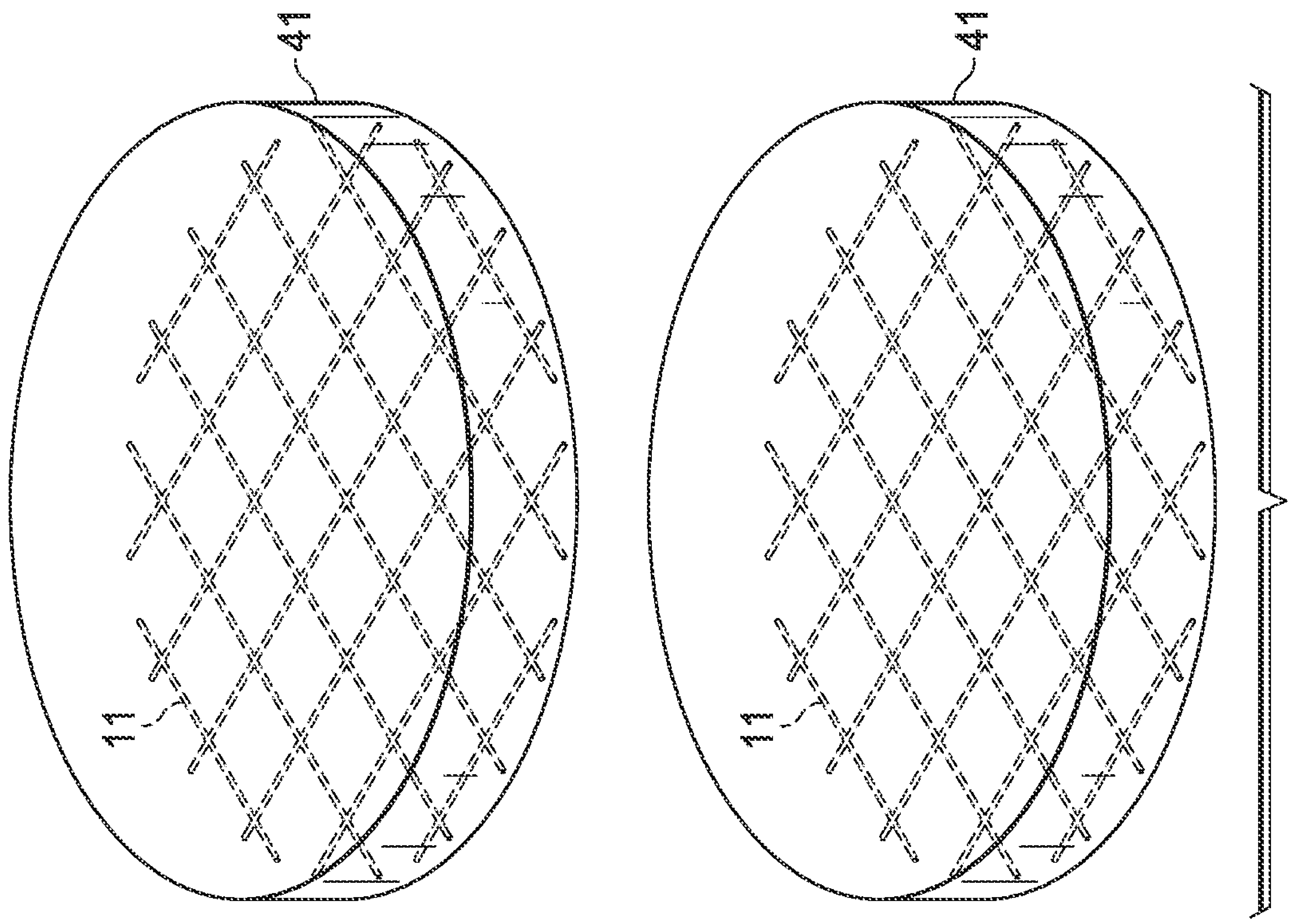


FIG. 4B

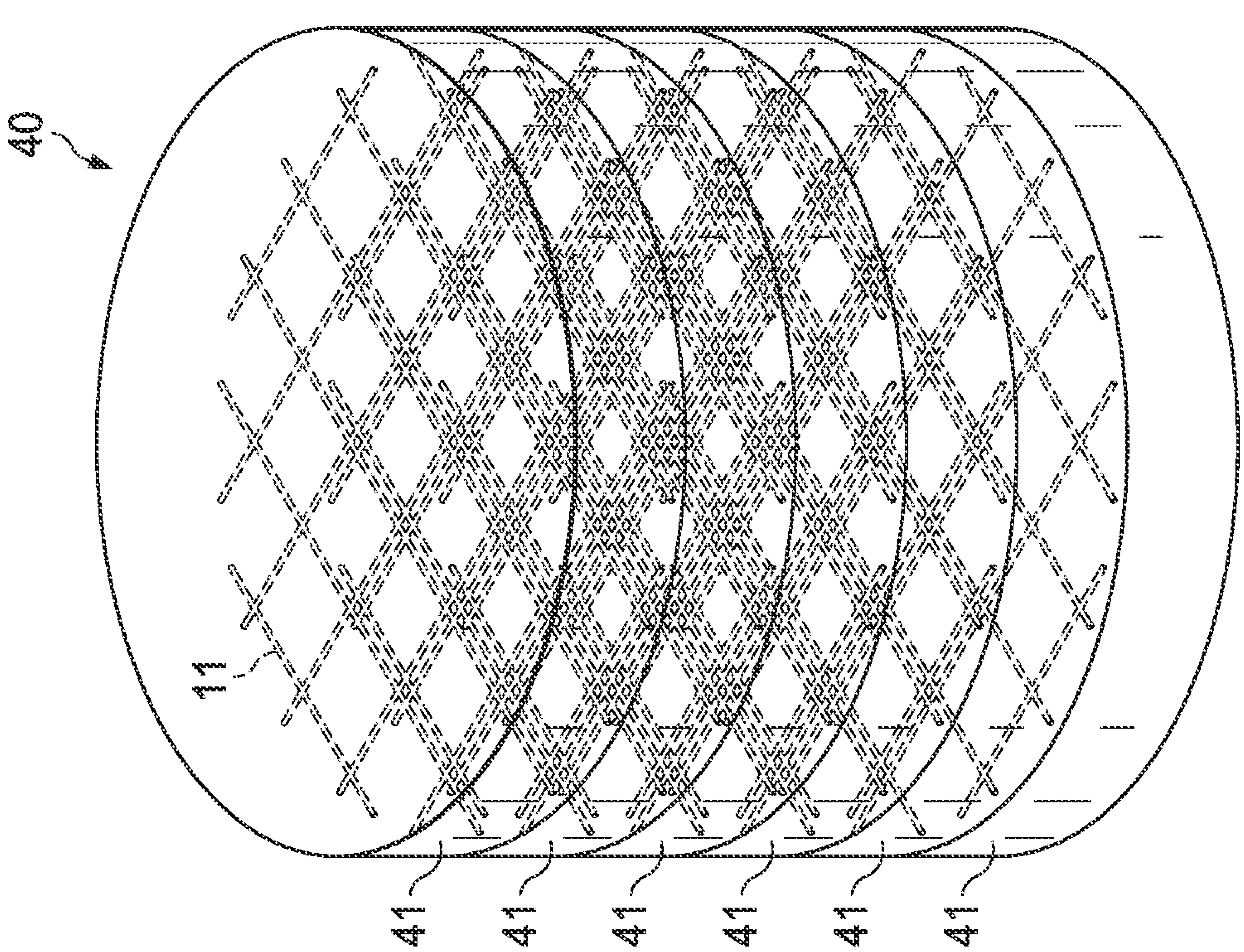


FIG. 4A

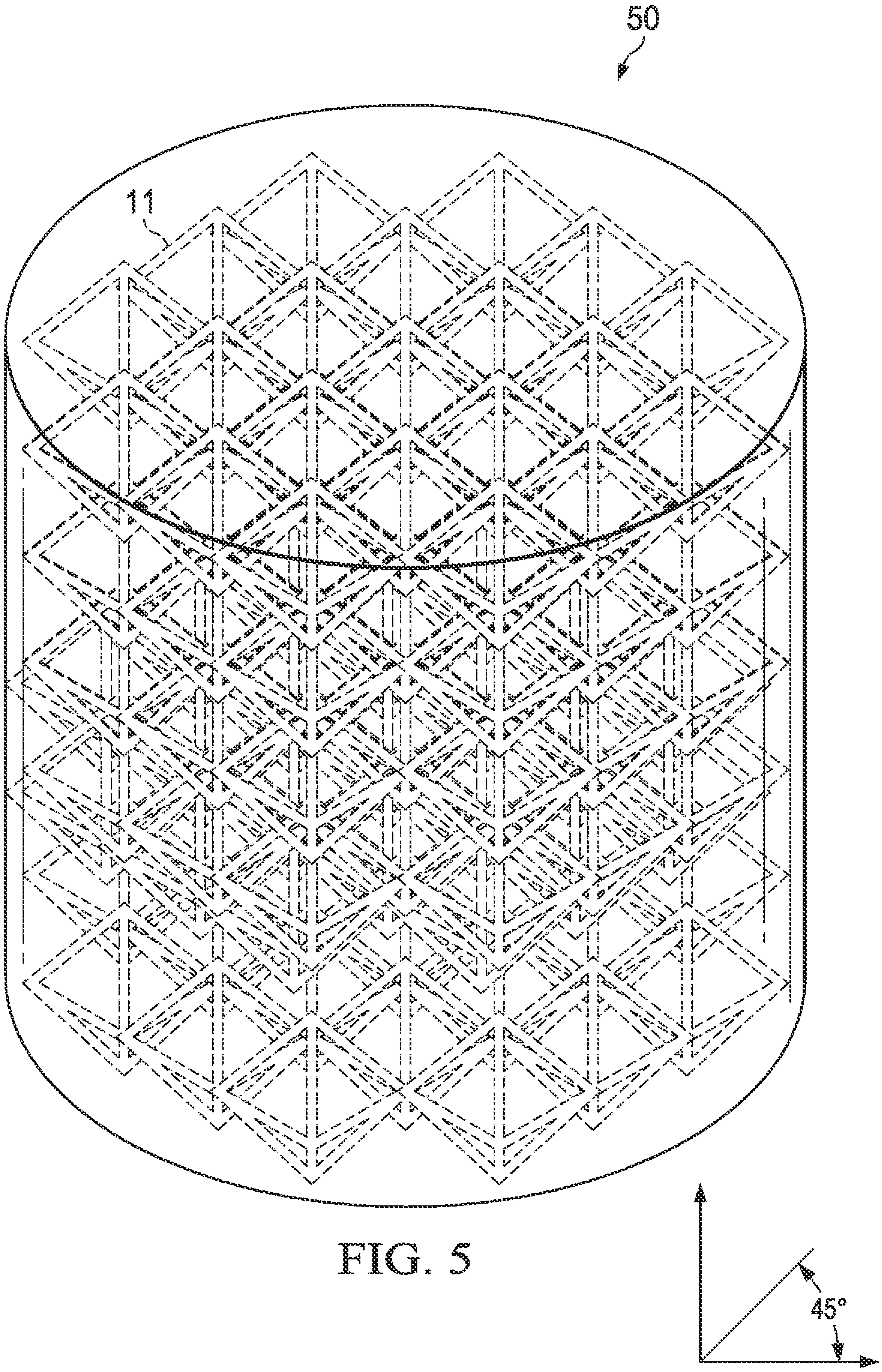


FIG. 5

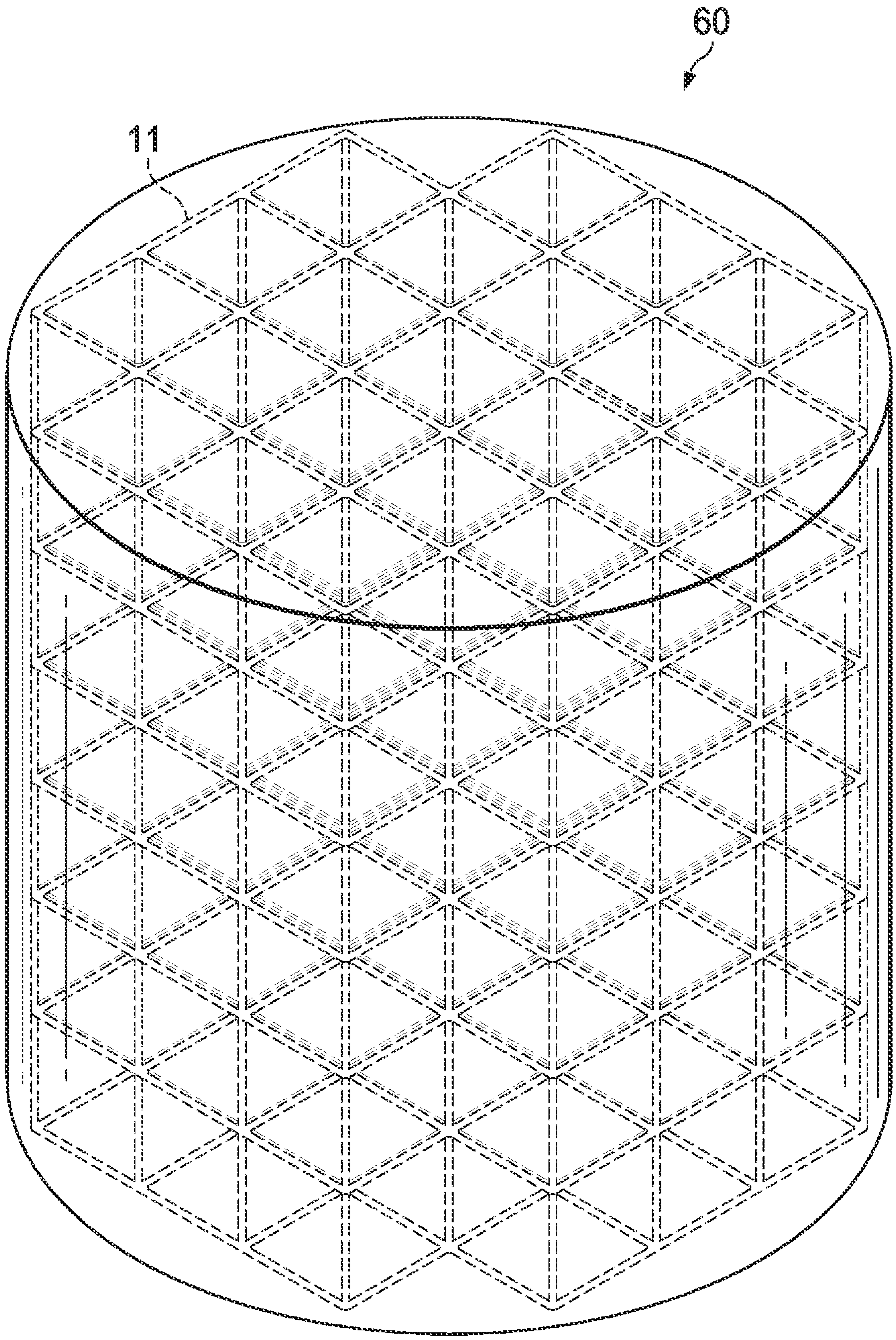


FIG. 6

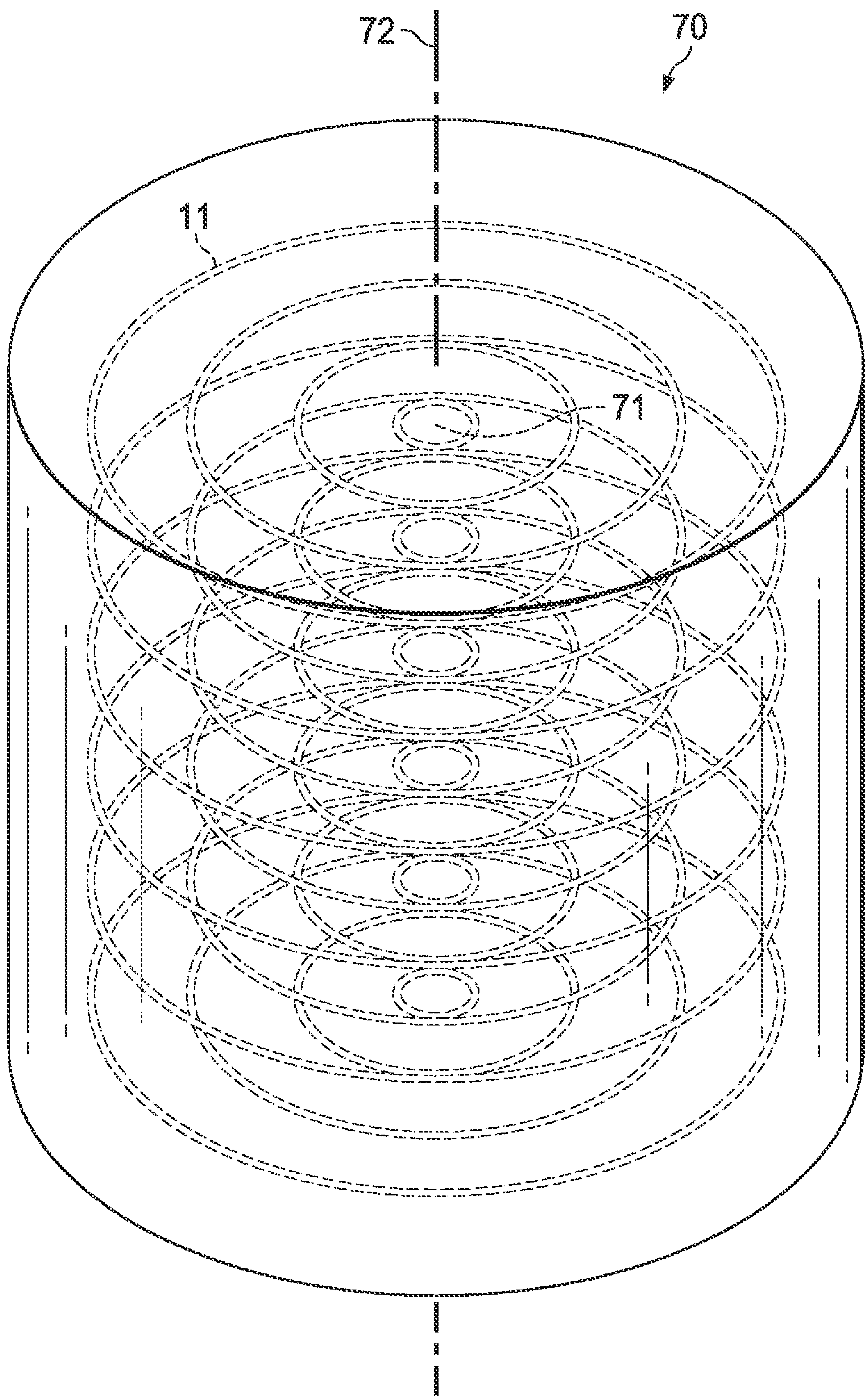


FIG. 7

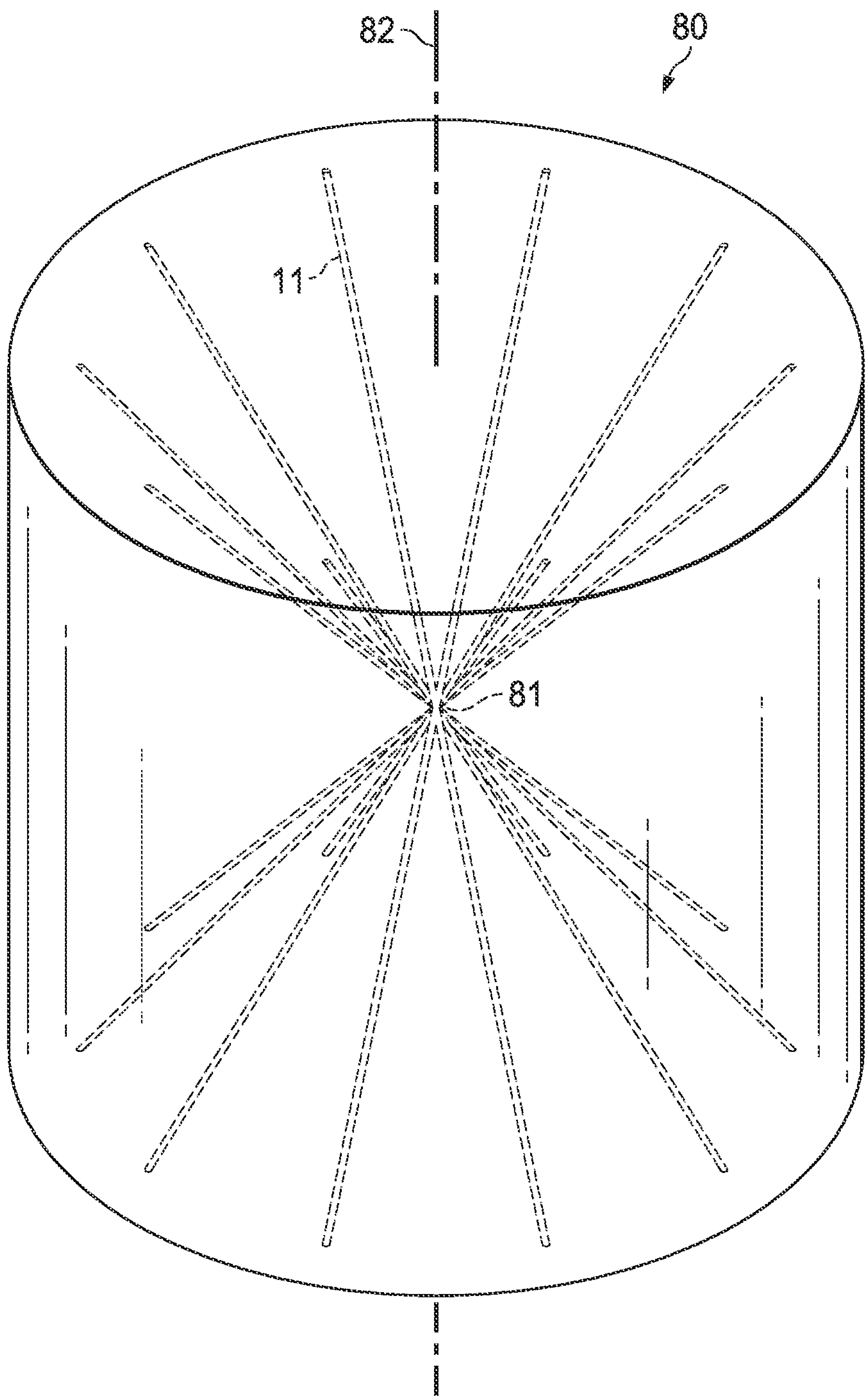


FIG. 8

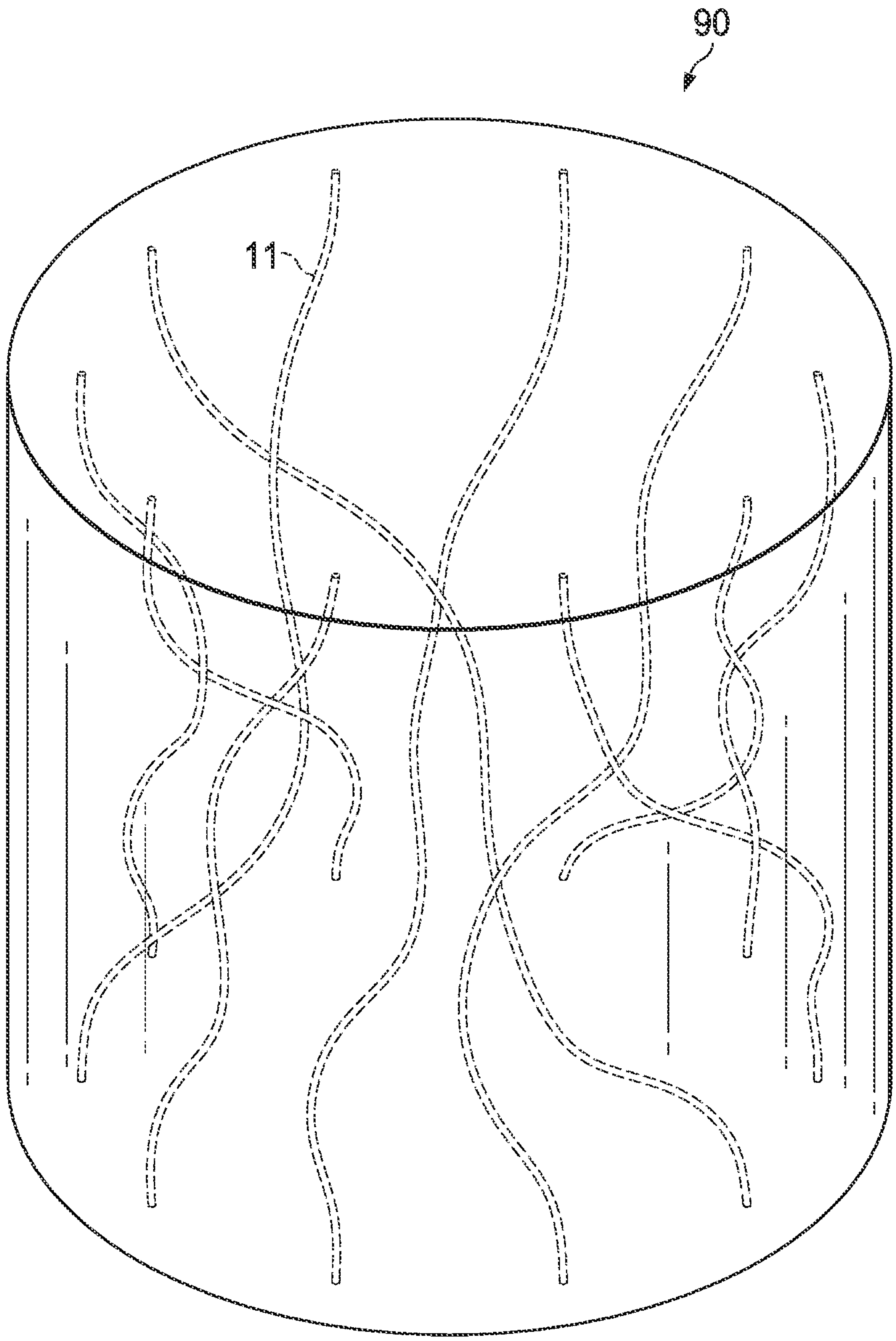


FIG. 9

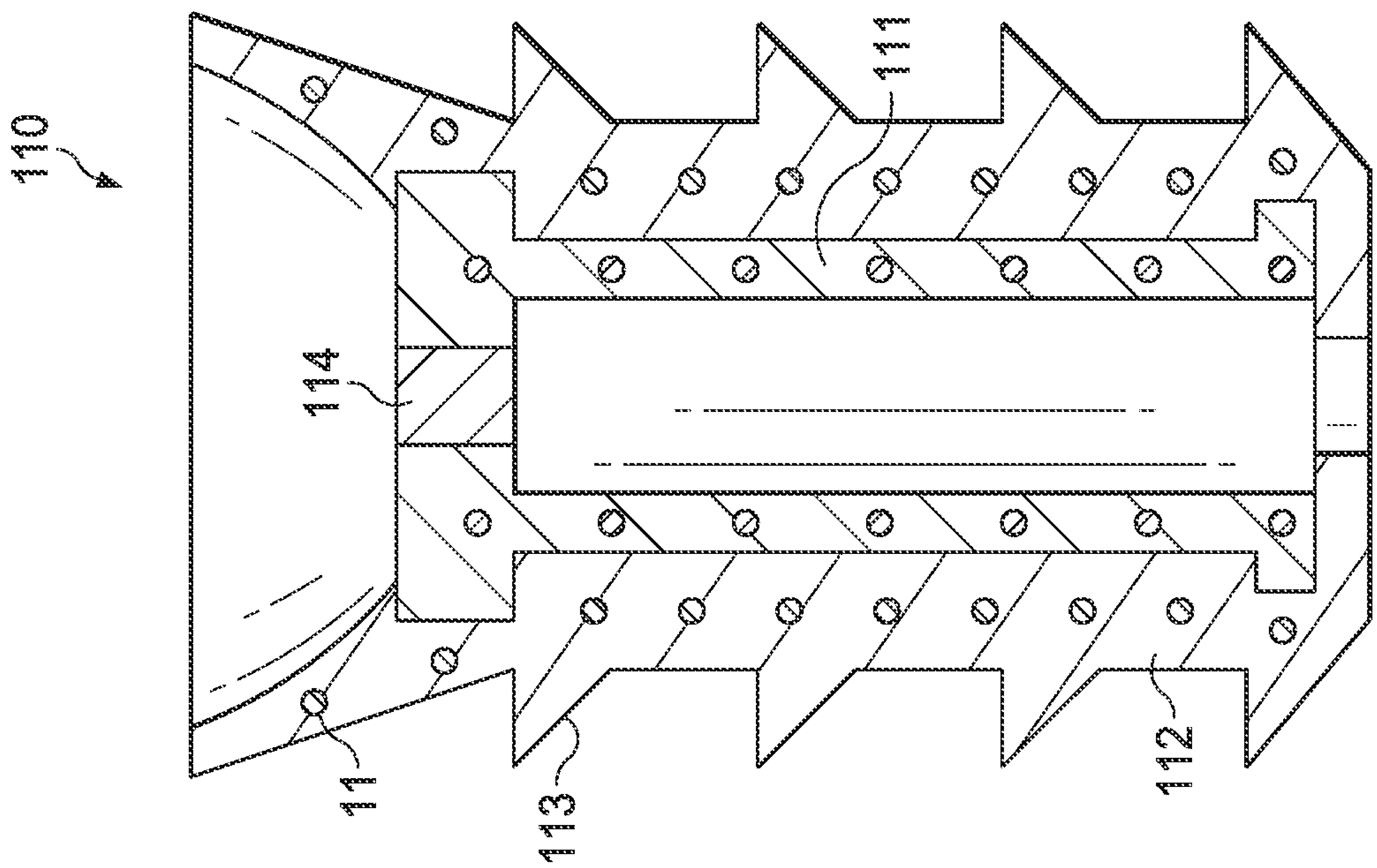


FIG. 11

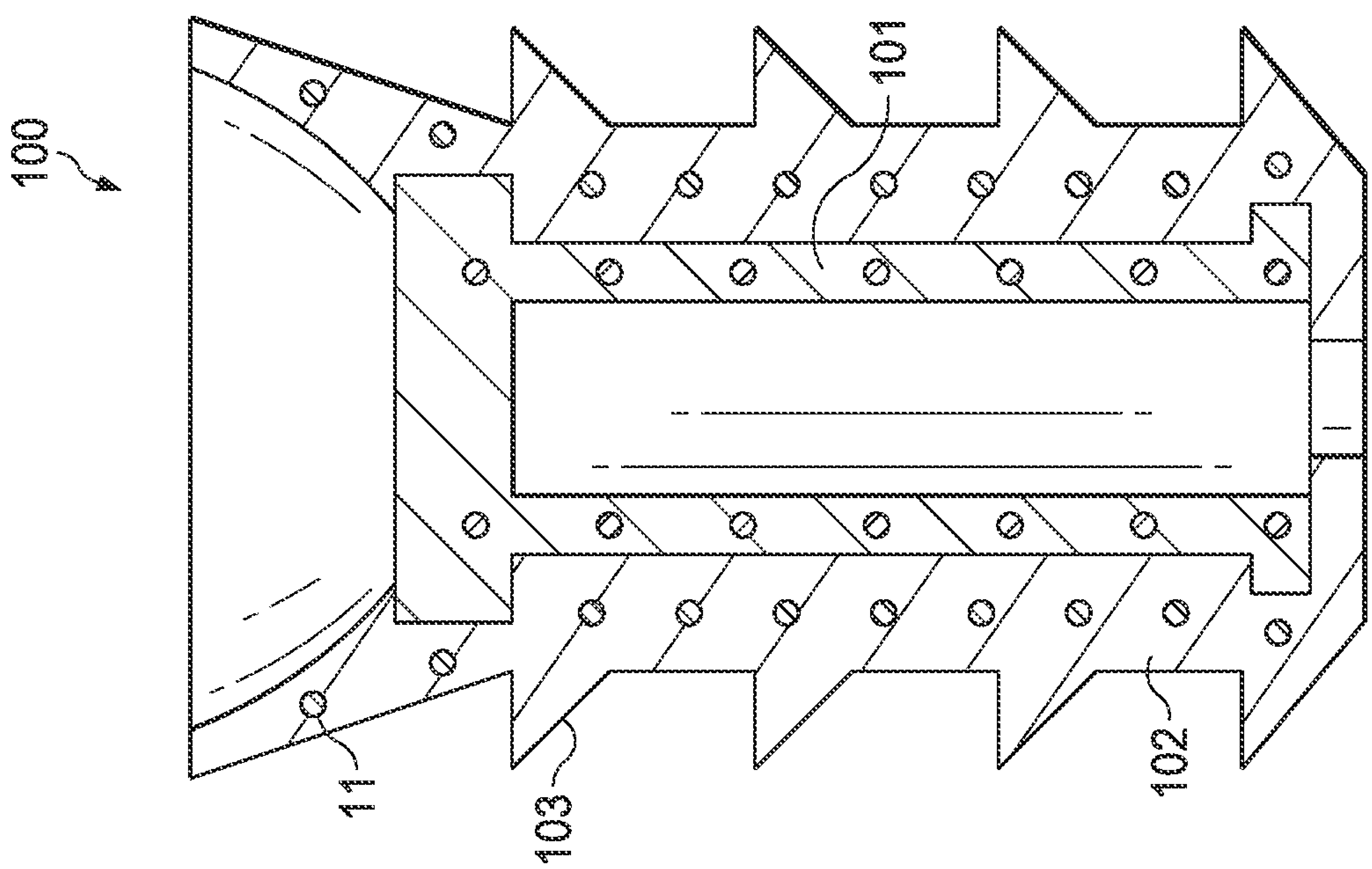


FIG. 10

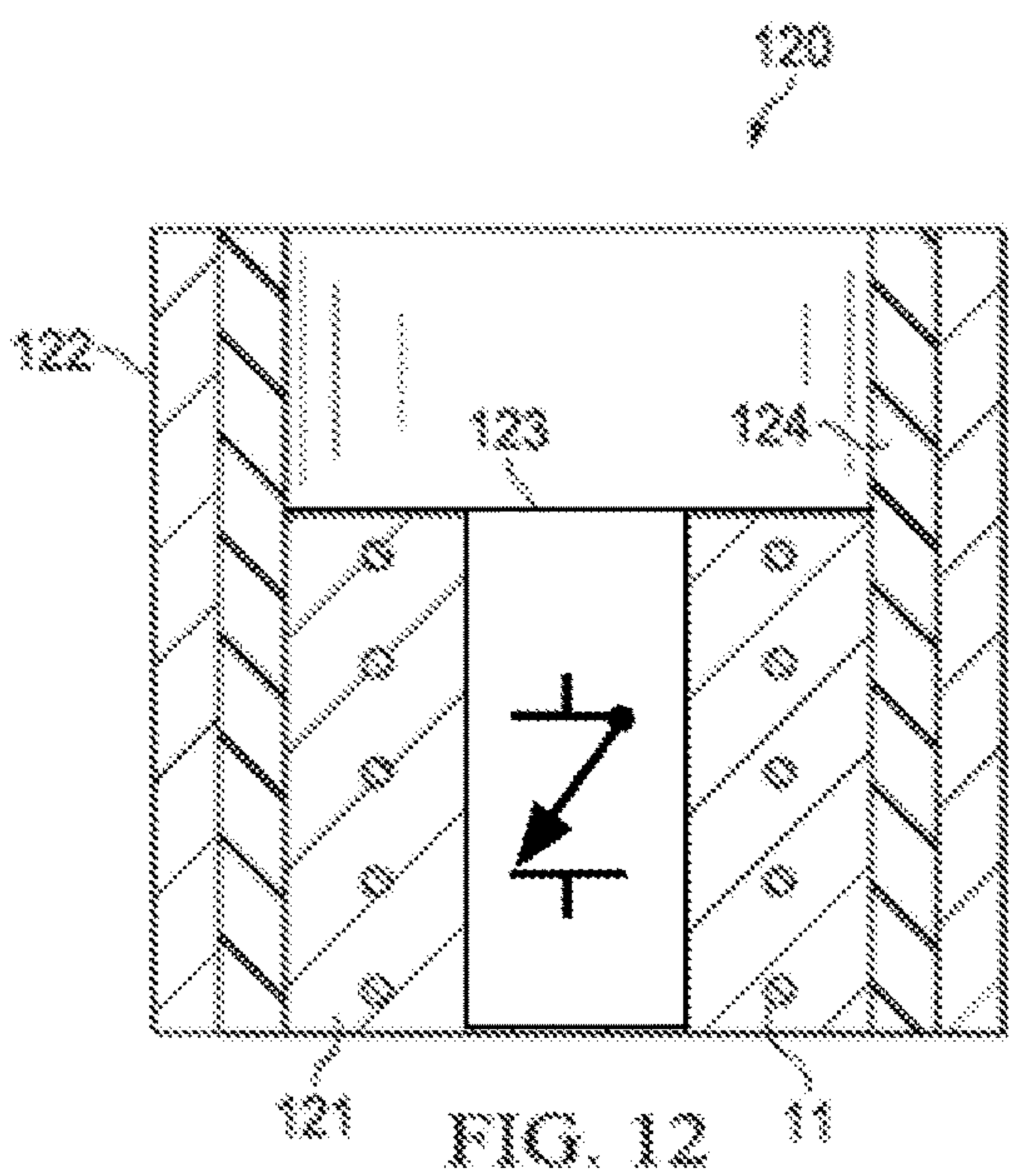


FIG. 12

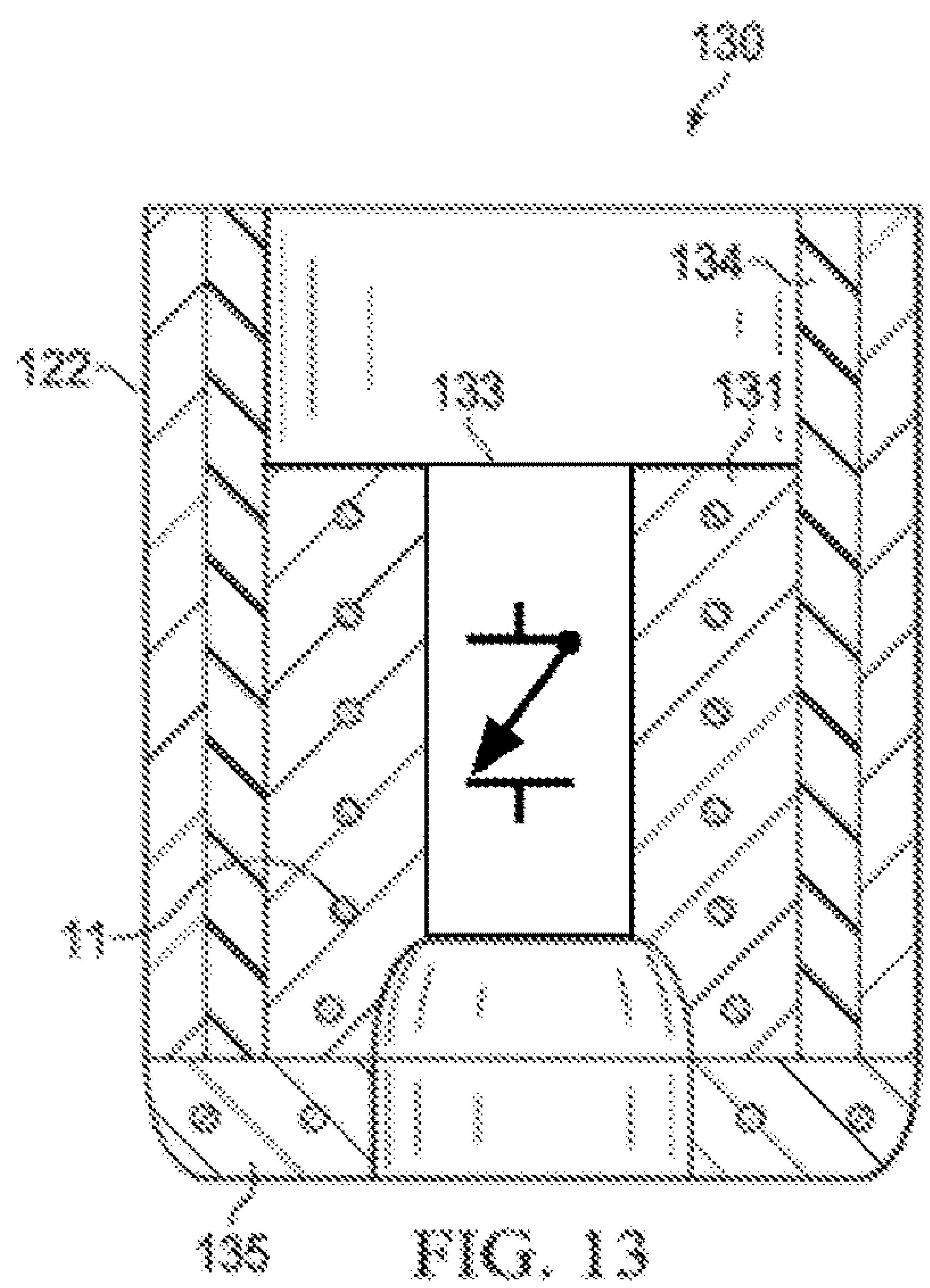
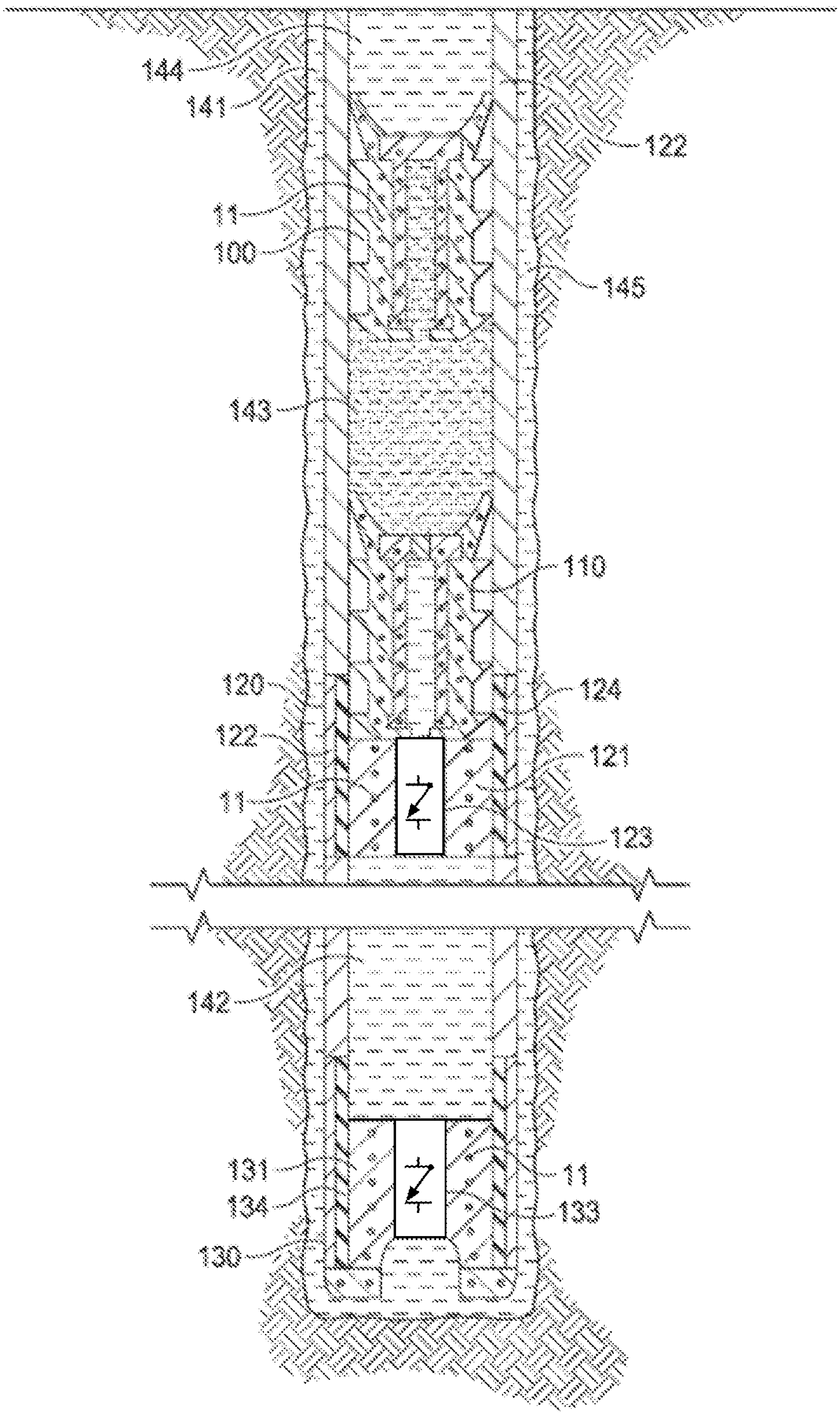


FIG. 13


144
141
122
11
100
145
143
110
120
124
122
121
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123
142
131
11
134
133
130

FIG. 14A

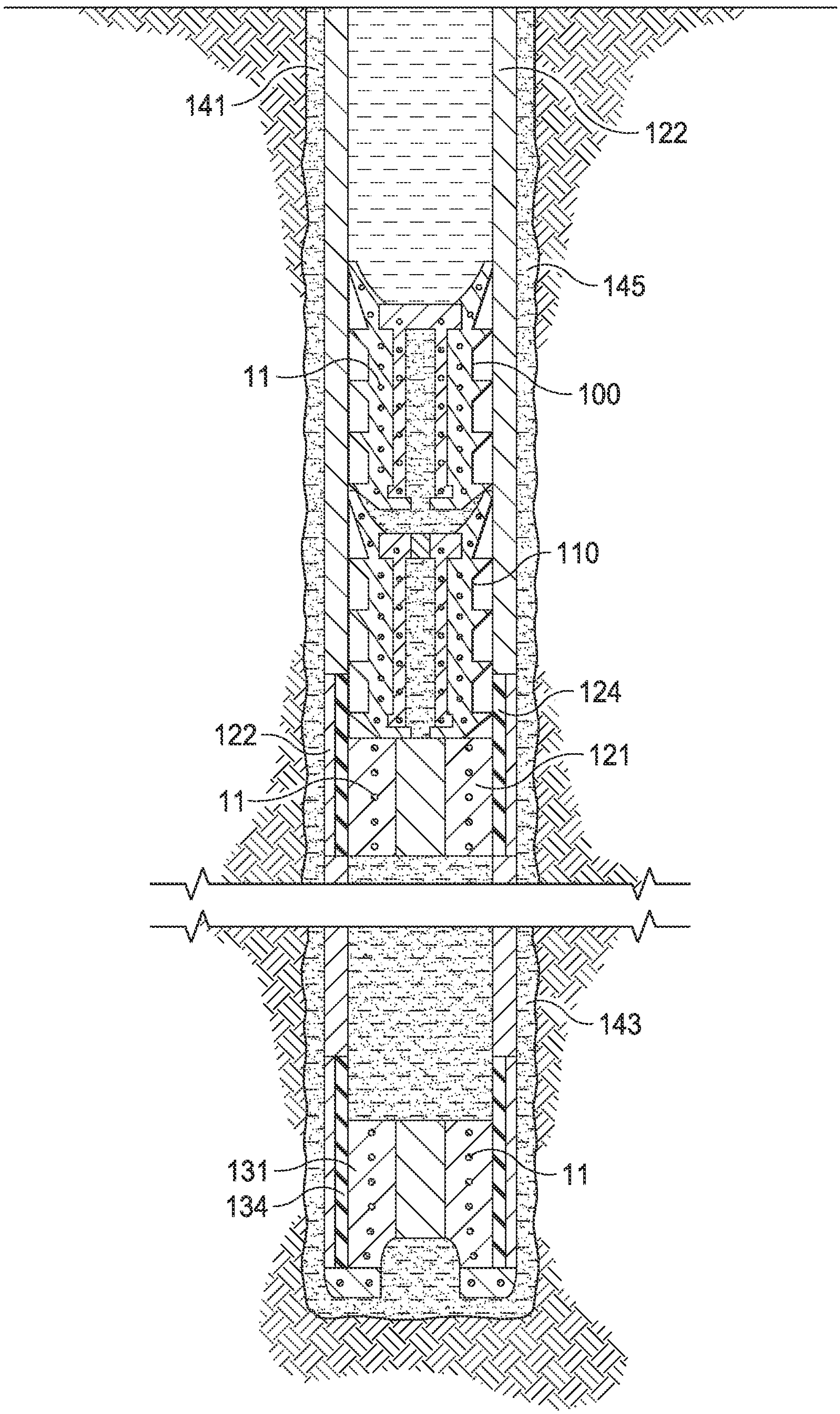

FIG. 14B

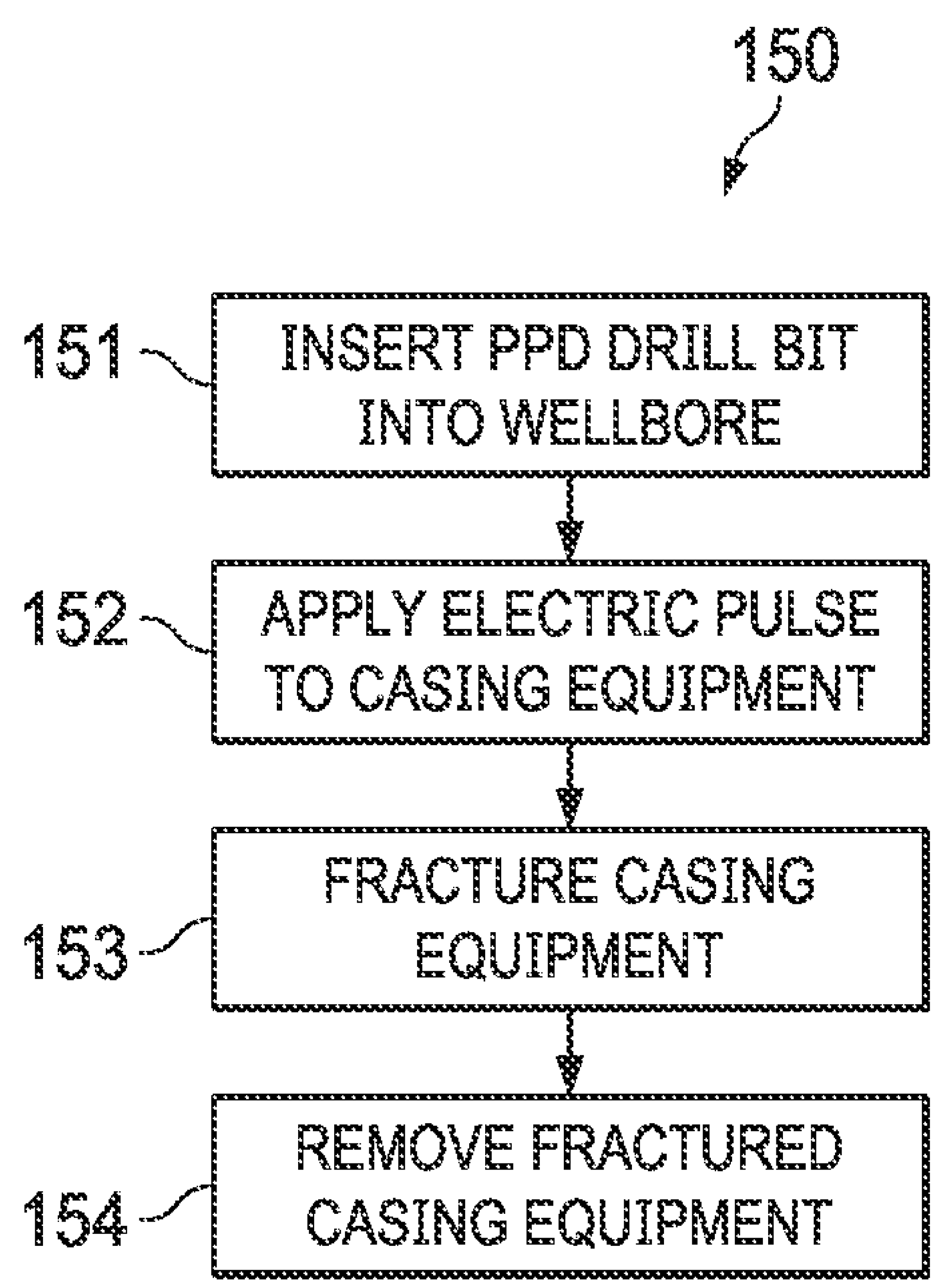
150
151
INSERT PPD DRILL BIT INTO WELLBORE
152
APPLY ELECTRIC PULSE TO CASING EQUIPMENT
153
FRACTURE CASING EQUIPMENT
154
REMOVE FRACTURED CASING EQUIPMENT

FIG. 15

CASING EQUIPMENT FOR PULSED POWER DRILLING

PRIORITY CLAIM

The present application is a U.S. National Stage Application of International Application No. PCT/US2019/049119 filed Aug. 30, 2019, which designates the United States.

TECHNICAL FIELD

The present disclosure generally relates to casing equipment for pulsed power drilling.

BACKGROUND

Wellbores are drilled to access and produce oil, gas, minerals, and other naturally-occurring deposits from subterranean geological formations. As the wellbore is drilled, a casing is inserted into the wellbore. The casing separates the drillstring from the walls of the wellbore. At some points along the wellbore, the casing can be cemented to the walls of the wellbore.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention and its features and advantages, reference is now made to the following description, taken in conjunction with the accompanying drawings, in which:

FIG. **1**A is a perspective view of a blank containing conducting filaments.

FIG. **1**B is an exploded view of the blank shown in FIG. **1**A.

FIG. **2**A is a perspective view of a blank containing conducting filaments.

FIG. **2**B is an exploded view of the blank shown in FIG. **2**A.

FIG. **3**A is a perspective view of a blank containing conducting filaments.

FIG. **3**B is an exploded view of the blank shown in FIG. **3**A.

FIG. **4**A is a perspective view of a blank containing conducting filaments.

FIG. **4**B is an exploded view of the blank shown in FIG. **4**A.

FIG. **5** is a perspective view of a blank containing conducting filaments.

FIG. **6** is a perspective view of a blank containing conducting filaments.

FIG. **7** is a perspective view of a blank containing conducting filaments.

FIG. **8** is a perspective view of a blank containing conducting filaments.

FIG. **9** is a perspective view of a blank containing conducting filaments.

FIG. **10** is a cross section view of a top plug containing conducting filaments.

FIG. **11** is a cross section view of a bottom plug containing conducting filaments.

FIG. **12** is a cross section view of a float collar containing conducting filaments.

FIG. **13** is a cross section view of a float shoe containing conductive filaments.

FIG. **14** is a cross section view of a wellbore cementing system. FIG. **14**A shows the system during cementing. FIG. **14**B shows the system after cementing.

FIG. **15** is a flowchart of a PPD-compatible wellbore-drillout method.

DETAILED DESCRIPTION

The present disclosure provides pulsed-power drilling (PPD)-compatible composite materials for casing equipment. The present disclosure provides not only a composite material, but also casing equipment, blanks that can be machined into casing equipment components, methods of manufacturing casing equipment, systems that include the casing equipment, and methods of drilling out casing equipment using PPD.

Some casing equipment used in wellbore cementing, such as the float shoe, the float collar, the bottom plug, and the top plug, are left in the wellbore path. Both the cement and the casing equipment must be removed to continue drilling.

Rotary drilling bits can drill out conventional casing equipment left in the wellbore that pulsed-power drilling systems conventionally cannot drill out. PPD systems use a high electric potential across electrodes of a pulsed-power drill bit to fracture rock. The high electric potential across the electrodes generates an electric field powerful enough to form an electric arc through rock formations. The arc temporarily electrically couples the drill bit's electrodes, allowing electric current to flow through the arc inside the rock formation. The arc greatly increases the temperature and pressure of the portion of the rock formation through which the current flows. The elevated temperature and pressure fractures the rock. The fractured rock is carried away from the bit by drilling fluid and the bit advances down the borehole. Conventional casing equipment is often made of non-conductive materials which can prevent PPD drill bit discharges from fracturing the casing equipment.

According to the teachings of this disclosure, by forming casing equipment with conductive filaments running through the casing equipment's non-conductive material, as described herein, the electric pulses of PPD systems may travel through the casing equipment and fracture it. A filament is a conductive filament if its conductivity is at least ten times greater, or at least 100 times greater, or at least 1000 times greater, than that of the non-conductive material. Likewise, a material is a non-conductive material if its conductivity is less than one tenth that of a conductive filament that runs through it. A conductive filament may have a conductivity of between 1×10^8 S/m and 1×10^7 S/m, 1×10^7 S/m and 1×10^6 S/m, 1×10^6 S/m and 1×10^5 S/m, 1×10^5 S/m and 1×10^4 S/m, and 1×10^4 S/m and 1×10^3 S/m, inclusive. A non-conductive material may have a conductivity between 1×10^{-8} S/m and 1×10^{-7} S/m, 1×10^{-7} S/m and 1×10^{-6} S/m, 1×10^{-6} S/m and 1×10^{-5} S/m, 1×10^{-5} S/m and 1×10^{-4} S/m, 1×10^{-4} S/m and 1×10^{-3} S/m, 1×10^{-3} S/m and 1×10^{-2} S/m, 1×10^{-2} S/m and 1×10^{-1} S/m, 1 S/m and 10 S/m, 10 S/m and 1×10^2 S/m, 1×10^2 S/m and 1×10^3 S/m, 1×10^3 S/m and 1×10^4 S/m, and 1×10^4 S/m and 1×10^5 S/m, inclusive.

PPD-suitable casing equipment may be made by machining blanks formed from non-conductive material with conductive filaments dispersed in non-conductive material. The blanks may be right circular cylinders, as depicted in FIGS. **1-9**, or they may be another shape suitable for machining, such as barrel-shaped or hollow cylinders.

The blanks shown in FIGS. **1-9** and casing equipment shown in FIGS. **10-12** include non-conductive material with conductive filaments **11** dispersed in the non-conductive material, rendering them PPD-compatible.

Non-conductive material may include concrete, ceramic, composite materials, such as fiberglass-reinforced plastic, and polymers, such as polyurethane, resin, plastic, and rubber, and any combinations thereof.

Conductive filaments may be formed from any conductive material that can form thin filaments. For example, conductive filaments may be include metals or metal alloys, such as aluminum, copper, iron, beryllium, titanium, gold, magnesium, manganese, nickel, platinum, tungsten, zinc, silver, alloys thereof, and any combinations thereof.

Conductive filaments may have a diameter of between 1 mm and 5 mm, between 5 mm and 4 mm, between 4 mm and 3 mm, between 3 mm and 2 mm, between 2 mm and 1 mm, between 1 mm and 0.5 mm, between 0.5 mm and 0.4 mm, between 0.4 mm and 0.3 mm, between 0.3 mm and 0.2 mm, between 0.2 mm and 0.1 mm, between 0.1 mm and 0.01 mm, or between 0.01 and 0.001 mm, inclusive.

Conductive filaments are dispersed in the non-conductive material so an electrical pulse from a PPD drill bit may flow through a conductive filament, heat it, and fragment the non-conductive material.

Conductive filaments may be dispersed in the non-conductive material using any suitable method. For example, holes may be drilled through the non-conductive material and then conductive filaments may be threaded through the holes.

Conductive filaments may be dispersed in the non-conductive material by using a form to hold filaments in place, pouring or injecting either molten non-conductive material or a resin into the form, and then letting the non-conductive material either set or cure. The form may be, for example, a mold. The filaments may be held in place by, for example, a porous foam.

If the non-conductive material is fiberglass-reinforced plastic, conductive filaments may be dispersed in the non-conductive material by weaving the conductive filaments into the fiberglass before resin is added to form the fiberglass-reinforced plastic.

FIG. **1**A is a perspective view of blank **10**. Blank **10** includes non-conductive material with conductive filaments **11** dispersed in the non-conductive material. Blank **10** may be formed of layers **12** of non-conductive material, or it may be a single piece. Conductive filaments **11** may be dispersed between all layers **12**, as shown, or only some layers **12**. Conductive filaments **11** in blank **10** may be dispersed radially about the cylinder axis **13** at regular intervals, as shown, or the intervals may be irregular. Conductive filaments **11** may be dispersed homogeneously or heterogeneously. Layers **12** may be affixed together by gluing, epoxying, heating, or any other suitable method to form blank **10**. Conductive filaments **11** are dispersed so an electrical pulse from a PPD drill bit may flow through conductive filament **11**, heat it, and fragment blank **10**. FIG. **1**B is an exploded view of FIG. **1**A, and shows conductive filaments **11** between each layer **12** of blank **10**.

FIG. **2**A is a perspective view of blank **20**. Blank **20** includes non-conductive material with conductive filaments **11** dispersed in the non-conductive material. Blank **20** may be formed of layers **21** of non-conductive material, or it may be a single piece. Conductive filaments **11** may be dispersed between all layers **21**, as shown, or only some layers **21**. Conductive filaments **11** in blank **20** may be dispersed in a regular series of parallel lines, as shown, or the lines may be irregularly spaced and may not be parallel. Conductive filaments **11** may be dispersed homogeneously or heterogeneously. Layers **21** may be affixed together by gluing, epoxying, heating, or any other suitable method to form blank **20**. Conductive filaments **11** are dispersed so an electrical pulse from a PPD drill bit may flow through conductive filament **11**, heat it, and fragment blank **20**. FIG. **2**B is an exploded view of FIG. **2**A, and shows conductive filaments **11** between each layer **21** of blank **20**.

FIG. **3**A is a perspective view of blank **30**. Blank **30** includes non-conductive material with conductive filaments **11** dispersed in the non-conductive material. Blank **30** may be formed of layers **31** of non-conductive material, or it may be a single piece. Conductive filaments **11** may be dispersed between all layers **31**, as shown, or only some layers **31**. Conductive filaments **11** in blank **30** may alternate between being dispersed radially about cylindrical axis **32** and being dispersed in a regular series of parallel lines, as shown, or they may alternate between different patterns or may not alternate. Conductive filaments **11** may be dispersed homogeneously or heterogeneously. Layers **31** may be affixed together by gluing, epoxying, heating, or any other suitable method to form blank **30**. Conductive filaments **11** are dispersed so an electrical pulse from a PPD drill bit may flow through conductive filament **11**, heat it, and fragment blank **30**. FIG. **3**B is an exploded view of FIG. **3**A, and shows conductive filaments **11** between each layer **31** of blank **30**.

FIG. **4**A is a perspective view of blank **40**. Blank **40** includes non-conductive material with conductive filaments **11** dispersed in the non-conductive material. Blank **40** may be formed of layers **41** of non-conductive material, or it may be a single piece. Conductive filaments **11** may be dispersed between all layers **41**, as shown, or only some layers **41**. Conductive filaments **11** in blank **40** may be dispersed in a regular 2-dimensional grid, as shown, or the grid may be irregular. Conductive filaments **11** may be dispersed homogeneously or heterogeneously. Layers **41** may be affixed together by gluing, epoxying, heating, or any other suitable method to form blank **40**. Conductive filaments **11** are dispersed so an electrical pulse from a PPD drill bit may flow through conductive filament **11**, heat it, and fragment blank **40**. FIG. **4**B is an exploded view of FIG. **4**A, and shows conductive filaments **11** between each layer **41** of blank **40**.

FIG. **5** is a perspective view of blank **50**. Blank **50** includes non-conductive material with conductive filaments **11** dispersed in the non-conductive material. Conductive filaments **11** in blank **50** may be dispersed in a regular 3-dimensional grid at a 45° angle to the base of blank **50**, as shown, or the grid may be irregular and may be disposed at any other angle relative to the base. Conductive filaments **11** may be dispersed homogeneously or heterogeneously. Conductive filaments **11** are dispersed so an electrical pulse from a PPD drill bit may flow through conductive filament **11**, heat it, and fragment blank **50**.

FIG. **6** is a perspective view of blank **60**. Blank **60** includes non-conductive material with conductive filaments **11** dispersed in the non-conductive material. Conductive filaments **11** in blank **60** may be dispersed in a regular 3-dimensional grid pattern at right angles, or parallel to, to the base of blank **60**, as shown, or the 3-dimensional grid pattern may be irregular. Conductive filaments **11** may be dispersed homogeneously or heterogeneously. Conductive filaments **11** are dispersed so an electrical pulse from a PPD drill bit may flow through conductive filament **11**, heat it, and fragment blank **60**.

FIG. **7** is a perspective view of blank **70**. Blank **70** includes non-conductive material with conductive filaments

11 dispersed in the non-conductive material. Conductive filaments **11** in blank **70** may be dispersed in rings about a point **71** on cylinder axis **72**, or the rings may be dispersed around other points within blank **70**. Conductive filaments **11** may be dispersed homogeneously or heterogeneously. Conductive filaments **11** are dispersed so an electrical pulse from a PPD drill bit may flow through conductive filament **11**, heat it, and fragment blank **70**.

FIG. **8** is a perspective view of blank **80**. Blank **80** includes non-conductive material with conductive filaments **11** dispersed in the non-conductive material. Conductive filaments **11** in blank **80** radiate out from point **81**. The conductive filaments **11** may be regularly or irregularly spaced. Point **81** may be on the cylinder axis **82**, as depicted, or may be at any other position. Conductive filaments **11** may be dispersed homogeneously or heterogeneously. Conductive filaments **11** are dispersed so an electrical pulse from a PPD drill bit may flow through conductive filament **11**, heat it, and fragment blank **80**.

FIG. **9** is a perspective view of blank **90**. Blank **90** includes non-conductive material with conductive filaments **11** dispersed in the non-conductive material. Conductive filaments **11** in blank **90** are dispersed irregularly and without pattern through blank **90**. Conductive filaments **11** may be dispersed homogeneously or heterogeneously. Conductive filaments **11** are dispersed so an electrical pulse from a PPD drill bit may flow through conductive filament **11**, heat it, and fragment blank **90**.

The present disclosure also provides PPD-suitable casing equipment form from a billet as described herein, such as wellbore-cementing plugs, including top plugs and bottom plugs. The plugs may be cylindrical and adapted to the casing. Any PPD-suitable well-bore cementing plugs may be formed from any of the blanks of FIGS. **1-9** or otherwise as disclosed herein.

FIG. **10** is a schematic view of PPD-suitable top plug **100**. Top plug **100** includes conductive filaments **11**. Top plug **100** may include both an inner body **101** and an outer body **102** as depicted, or it may only have a single body. A body may include non-conductive materials and conductive filaments in portions to be fragmented by the PPD bit. Both inner body **101** and outer body **102** may include the same non-conductive material, or different non-conductive materials. Outer body **102** may have fins **103** to clear material from the casing as top plug **100** descends. Top plug **100** may be formed by machining a blank, or it may be formed by other methods, such as molding. Conductive filaments **11** may be dispersed in top plug **100** as described in FIGS. **1-9**, or in other suitable ways. Conductive filaments may be dispersed homogeneously or heterogeneously in top plug **100**. Top plug **100** may have a hollow interior defined by a body, such as the inner body **101**, as depicted, or top plug **100** may be solid.

FIG. **11** is a schematic view of bottom PPD-suitable plug **110**. Bottom plug **110** includes conductive filaments **11**. Bottom plug **110** may include both an inner body **111** and an outer body **112** as depicted, or it may only have a single body. Inner body **111** and outer body **112** may include non-conductive material. Both inner body **111** and outer body **112** may include the same non-conductive material, or different non-conductive material. Outer body **112** may have fins **113** to clear material from the casing as bottom plug **110** descends. Bottom plug **110** may be formed by machining a blank, or it may be formed by other methods, such as molding. Conductive filaments **11** may be dispersed in bottom plug **110** as described in FIGS. **1-9**, or in other suitable ways. Conductive filaments **11** may be dispersed homogeneously or heterogeneously in bottom plug **110**. Bottom plug **110** may have a hollow interior defined by a body, such as inner body **111**, as depicted, or bottom plug **110** may be solid. Bottom plug **110** may also have rupturable diaphragm **114**, located at an end of the hollow interior, which ruptures on application of sufficient pressure and allows fluid to pass through bottom plug **110**.

The present disclosure also provides wellbore-cementing float equipment. Float collars and float shoes are examples of float equipment. Any wellbore-cementing float equipment may be formed from any of the blanks of FIGS. **1-9** or otherwise as disclosed herein. Float collars and float shoes may have casing segments with PPD-drillable material affixed to the casing segment inner surface. A check valve may be attached to the drillable material, which allows material to pass downhole through the float collar or float shoe, but prevents the material from flowing back uphole. The check valve may also be drillable.

FIG. **12** is a schematic view of float collar **120**. Float collar **120** includes conductive filaments **11**, drillable material **121**, casing segment **122**, and casing segment inner surface **124**. Drillable material **121** includes non-conductive material and conductive filaments **11** dispersed in the non-conductive material. The non-conductive material may be any such material identified herein, but frequently it includes concrete. Conductive filaments **11** may be dispersed in drillable material **121** as described in FIGS. **1-9**, or in other suitable ways. Conductive filaments **11** may be dispersed homogeneously or heterogeneously in drillable material **121**. Drillable material **121** is attached to the inner surface **124** and holds check valve **123** in place. Check valve **123** allows fluid to pass downhole through float collar **120** but does not allow the fluid to travel back uphole. Check valve **123** may also include non-conductive material and conductive filaments **11** dispersed in the non-conductive material. Inner surface **124** may electrically insulate casing segment **122**, which prevents electrical discharges from a PPD drill bit from arcing to casing segment **122**. Inner surface **124** may be a layer of, coating on, or homogenous part of casing segment **122**. Inner surface **124** may cover only casing **122** near the float collar, as depicted in FIG. **12**, or inner surface **124** may cover any other portion of casing **122**. Inner surface **124** may include any suitable material, such as a polymer, like plastics, resins, or rubber, or a composite material, such as fiberglass.

FIG. **13** is a schematic view of float shoe **130**. Float shoe **130** includes drillable material **131**, casing segment **122**, and casing segment inner surface **134**. Drillable material **131** includes non-conductive material and conductive filaments **11** dispersed in the non-conductive material. Conductive filaments **11** may be dispersed in drillable material **131** as described in FIGS. **1-9**, or in other suitable ways. Conductive filaments **11** may be dispersed homogeneously or heterogeneously in drillable material **131**. Drillable material **131** is attached to inner surface **134** and holds check valve **133** in place. Check valve **133** allows fluid to pass downhole through float shoe **130** but does not allow fluid to travel back uphole. Check valve **133** may also include non-conductive material and conductive filaments **11** dispersed in the non-conductive material. Inner surface **134** may electrically insulate casing segment **122**, which prevents electrical discharges from a PPD drill bit from arcing to casing segment **122**. Inner surface **134** may be a layer of, coating on, or homogenous part of casing segment **122**. Inner surface **134** may cover only casing **122** near the float collar, as depicted in FIG. **12**, or inner surface **134** may cover any other portion of casing segment **122**. Inner surface **134** may include any suitable material, such as a polymer, such as plastics, resins, or rubber, or a composite material, such as fiberglass. Float shoe **130** may also have shoe **135** attached to the bottom of casing segment **122**. Shoe **135** protects the bottom of float shoe **130** from the wellbore, and the rounded edges of shoe **135** help guide the casing string down the wellbore. Shoe **135** may include shoe non-conductive material and shoe conductive filaments **11** dispersed in the shoe non-conductive material. Shoe non-conductive material may be different from the non-conductive material of the drillable material, shoe conductive filaments may be different from the conductive filaments of the drillable material, or both.

The present disclosure also provides PPD-compatible wellbore-cementing systems. Systems may include a float shoe at the bottom of the casing string that includes a check valve to prevent fluid pumped past the float shoe from flowing back uphole. Systems may include a float collar that includes a check valve to prevent fluid pumped past the float collar from flowing back uphole. Systems may include a bottom plug to maintain separation between the cement pumped into the casing and the drilling fluid already in the casing. Systems may include a top plug to maintain separation between the cement pumped into the casing and the fluid pumped into the casing after the cement. Each of the float shoe, float collar, top plug, and bottom plug, or any combination thereof, may include non-conductive materials with conductive filaments dispersed in the non-conductive material, which allows it to be drilled out with PPD. Systems may include a PPD drill.

FIG. **14**A-B are schematic views of a PPD-compatible wellbore-cementing system. FIG. **14**A shows the cementing system after top plug **100** is inserted into casing segment **122** but before cement **143** has entered annulus **145**. Casing segment **122** may be positioned in wellbore **141**. Bottom plug **110** rests on the drillable material **121** of float collar **120**. Bottom plug **110** separates drilling fluid **142** from cement **143**. Top plug **100** separates cement **143** from pump fluid **144**. Pump fluid **144** pushes cement **143** into annulus **145**. Check valve **123** on float collar **120** and check valve **133** on float shoe **130** prevent the cement from traveling back up once it has passed check valves **123** and **133** and entered annulus **145**. Conductive filaments **11** allow the casing equipment to be drilled by a PPD system. Inner surfaces **124** and **134** may electrically insulate casing **122** to prevent the PPD drill bit electric discharges from arcing to casing segment **122** while the PPD drill bit drills out drillable material **121** and **131**. Float-collar non-conductive material may be different from the non-conductive material of the drillable material, float-collar conductive filaments may be different from the conductive filaments of the drillable material, or both.

FIG. **14**B is a schematic view of a wellbore-cementing system after bottom plug **110** has ruptured and annulus **145** has filled with cement **143**. Top plug **100**, bottom plug **110**, float collar drillable material **121**, and float shoe drillable material **131** are in the path of wellbore **141** and may be drilled out. Conductive filaments **11** allow the casing equipment in the path of the wellbore to be drilled out by a PPD system. Inner surfaces **124** and **134** may electrically insulate casing segment **122** to prevent the PPD drill bit electric discharges from arcing to casing segment **122** while the PPD drill bit drills out drillable material **121** and **131**.

FIG. **15** is a flowchart describing PPD-compatible wellbore-drillout method **150**. In step **151** of method **150**, the PPD drill bit is lowered into the wellbore containing the PPD-compatible casing equipment. As described previously, the PPD-compatible casing equipment includes both non-conductive material and conductive filaments distributed in the non-conductive material. In step **152**, the PPD drill bit applies an electrical pulse to the PPD-compatible casing equipment that flows through at least one of the conductive filaments, heating it. In step **153**, the heated conductive filament fractures the non-conductive material, breaking the PPD-compatible casing equipment into smaller pieces. Finally, in step **154**, the smaller pieces of fractured PPD-compatible casing equipment are swept away by drilling fluid pumped into the wellbore.

The present disclosure further includes variations of the materials, blanks, casing equipment, and methods disclosed herein. For example, the non-conductive material with conductive filaments may be formed by dispersing conductive filaments homogeneously in the non-conductive material, or only in some portions of the non-conductive material. Different dispersions will result in different properties. A non-conductive material with fewer conductive filaments may fragment into larger pieces, for instance. A non-conductive material with more conductive filaments may require stronger electrical pulses to heat the conductive filaments. Conductive filaments may be dispersed in a pattern that causes the non-conductive material to fragment into specific shapes.

The present disclosure includes a plug for cementing a wellbore. The plug may include at least one body including a non-conductive material with conductive filaments dispersed within the non-conductive material.

According to further embodiments, which may be combined with one another and with any disclosure of a plug herein, unless clearly mutually exclusive:

i) the plug may include an inner body and an outer body;
i-a) the plug may further include fins that project from the outer body of the plug;
ii) the plug may include a cylinder;
iii) at least one body of the plug may further define a hollow interior;
iii-a) the plug may further include a rupturable diaphragm at an end of the hollow interior;
iv) the non-conductive material may include at least one of the group consisting of concrete, ceramic, a composite material, fiberglass-reinforced plastic, a polymers, polyurethane, resin, plastic, rubber, and any combinations thereof;
iv) the conductive filaments may include at least one of the group consisting of aluminum, copper, iron, beryllium, titanium, gold, magnesium, manganese, nickel, platinum, tungsten, zinc, silver, alloys thereof, and any combinations thereof;
v) the conductive filaments may be dispersed homogeneously in the non-conductive material;
vi) the conductive filaments may be dispersed in a pattern in the non-conductive material;
vi-a) the pattern may be a 2-dimensional pattern;
vi-b) the pattern may be a 3-dimensional pattern;
vii) the conductive filaments may be dispersed heterogeneously in the non-conductive material.

The present disclosure includes float equipment for cementing a wellbore. The float equipment may include a casing segment including an inner surface, drillable material affixed to the inner surface of the casing segment, and a check valve attached to the drillable material. The drillable material may include a non-conductive material and conductive filaments dispersed within the non-conductive material.

According to further embodiments, which may be combined with one another and with any disclosure of a blank herein, unless clearly mutually exclusive:

i) the float equipment may further include a rounded shoe attached to the bottom of the casing segment, the rounded shoe including a shoe non-conductive material and shoe conductive filaments dispersed within the shoe non-conductive material.

i-a) the shoe non-conductive material may be different from the non-conductive material of the drillable material, shoe conductive filaments may be different from the conductive filaments of the drillable material, or both.

ii) the check valve may further include a check-valve non-conductive material and check-valve conductive filaments dispersed within the check-valve non-conductive material.

ii-a) check valve non-conductive material may be different from the non-conductive material of the drillable material, the check valve conductive filaments may be different from the conductive filaments of the drillable material, or both.

iii) the non-conductive material may include at least one of the group consisting of concrete, ceramic, a composite material, fiberglass-reinforced plastic, a polymers, polyurethane, resin, plastic, rubber, and any combinations thereof;

iv) the conductive filaments may include at least one of the group consisting of aluminum, copper, iron, beryllium, titanium, gold, magnesium, manganese, nickel, platinum, tungsten, zinc, silver, alloys thereof, and any combinations thereof;

v) the conductive filaments may be dispersed homogeneously in the non-conductive material;

vi) the conductive filaments may be dispersed in a pattern in the non-conductive material;

vi-a) the pattern may be a 2-dimensional pattern;

vi-b) the pattern may be a 3-dimensional pattern;

vii) the conductive filaments may be dispersed heterogeneously in the non-conductive material.

The plugs and float collars disclosed above may be used in combination with one another in a wellbore being drilled using PPD.

Although the present disclosure has been described with several embodiments, various changes and modifications may be suggested to one skilled in the art. It is intended that the present disclosure encompasses such various changes and modifications as falling within the scope of the appended claims.

The invention claimed is:

1. A plug for cementing a wellbore, the plug comprising:
at least one body including
an inner body including a first non-conductive material with conductive filaments dispersed within the first non-conductive material; and
an outer body including a second non-conductive material with conductive filaments dispersed within the second non-conductive material, wherein the second non-conductive material is different from the first non-conductive material.

2. The plug of claim **1**, wherein the plug is cylindrical.

3. The plug of claim **2**, wherein the plug further comprises a rupturable diaphragm at an end of the hollow interior.

4. The plug of claim **1**, further comprising fins that project from the outer body of the plug.

5. The plug of claim **1**, wherein the first and second non-conductive materials comprise at least two of the group consisting of concrete, ceramic, a composite material, fiberglass-reinforced plastic, a polymers, polyurethane, resin, plastic, rubber, and any combinations thereof.

6. The plug of claim **1**, wherein the conductive filaments comprise at least one of the group consisting of aluminum, copper, iron, beryllium, titanium, gold, magnesium, manganese, nickel, platinum, tungsten, zinc, silver, alloys thereof, and any combinations thereof.

7. The plug of claim **1**, wherein the conductive filaments are dispersed homogeneously in the first and second non-conductive materials.

8. The plug of claim **1**, wherein the conductive filaments are dispersed in a 2-dimensional or 3-dimensional pattern in the first and second non-conductive materials.

9. The plug of claim **1**, wherein the conductive filaments are dispersed heterogeneously in the first and second non-conductive materials.

10. Float equipment for cementing a wellbore, the float equipment comprising:
a casing segment including an inner surface;
drillable material affixed to the inner surface of the casing segment, the drillable material including
a non-conductive material; and
conductive filaments dispersed within the non-conductive material; and
a check valve attached to the drillable material, the check valve including a check-valve non-conductive material and check-valve conductive filaments dispersed within the check-valve non-conductive material.

11. The float equipment of claim **10**, further comprising a rounded shoe attached to the bottom of the casing segment, the rounded shoe comprising:
a shoe non-conductive material; and
shoe conductive filaments dispersed within the shoe non-conductive material.

12. The float equipment of claim **11**, wherein the shoe non-conductive material is different from the non-conductive material of the drillable material, the shoe conductive filaments are different from the conductive filaments of the drillable material, or both.

13. The float equipment of claim **10**, wherein the check valve non-conductive material is different from the non-conductive material of the drillable material, the check valve conductive filaments are different from the conductive filaments of the drillable material, or both.

14. The float equipment of claim **10**, wherein the non-conductive material of the drillable material comprises at least one of the group consisting of concrete, ceramic, a composite material, fiberglass-reinforced plastic, a polymers, polyurethane, resin, plastic, rubber, and any combinations thereof.

15. The float equipment of claim **10**, wherein the conductive filaments of the drillable material comprise at least one of the group consisting of aluminum, copper, iron, beryllium, titanium, gold, magnesium, manganese, nickel, platinum, tungsten, zinc, silver, alloys thereof, and any combinations thereof.

16. The float equipment of claim **10**, wherein the conductive filaments of the drillable material are dispersed homogeneously in the non-conductive material of the drillable material.

17. The float equipment of claim **10**, wherein the conductive filaments of the drillable material are dispersed in a 2-dimensional or 3-dimensional pattern in the non-conductive material of the drillable material.

18. The float equipment of claim **10**, wherein the conductive filaments of the drillable material are dispersed heterogeneously in the non-conductive material of the drillable material.

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